VALIDATION OF AN EULERIAN MODEL FOR BUBBLY FLOWS AND THREE-DIMENSIONAL NUMERICAL SIMULATIONS

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Vertical bubble columns are widely used in the chemical and process engineering. In these experiments important phenomena like bubble street formation of gas into a liquid with or without an overall recirculation of the continuous phase, zero void fraction distribution near the wall, turbulence and so on can be observed in numerous industrial applications: oxidation processes, fermentation, column flotation, destratification. The variation of the diameter of the column, of the height, of the superficial liquid velocity, of the bubble street diameter and of the gas fraction in the bubble street, even of the shape of the sprinkler influence the output of the experiment. Since the large-scale experiments can be very expensive, numerical models which can be used to simulate an operation of a real column are extremely important. A fundamental problem in multiphase flows is the prediction of the velocity and the gas hold-up profles for three-dimensional laminar bubbly two-phase flow in a pipe. In bubble columns the gas phase exists as a dispersed phase in the liquid. In our study we deal with the homogeneous regime only. An Eulerian approach has been used. The multiphase flow model is based on a set of equations derived through averaging of the equations for each phase. The closure problem can then be resolved by setting up additional relations which follow from some physical considerations or experimental data. This type of models work relatively well even at very high void fractions where the simple Lagrangian tracking models clearly fail.

Our numerical scheme consists in: the advective terms in both the continuity and momentum equations for both phases are split via a consistent splitting and integrated by means of the method of characteristics. We use second order backward difference scheme in time. For the pressure we use a modified incremental projection method. The remaining problem is solved by means of a stabilized finite element method. We use P2-P1 (Taylor-Hood) tetrahedral finite elements having 10 velocity nodes and 4 pressure nodes. The stabilized Galerkin technique we used is based on a two-level hierarchical decomposition of the approximation space and it basically introduces two more terms in our formulation: a stabilization term and a shock capturing term. The performance of our scheme is evaluated on two major benchmark problems: the sedimentation problem of the two phases where the importance of the shock capturing term and the stabilization term are illustrated and the Rayleigh-Taylor instability problem. Comparison with analytical solutions and with results provided by other authors are presented. Since the model is strongly nonlinear we tested its performance on a problem involving a nonlinear wave propagation in a periodic domain. Comparisons with other authors for this problem will be provided. There are many experiments in the literature that show the flow pattern which is induced by a rising bubble street in a liquid column. Most of the papers which try to compare their numerical simulations with the experiments are either two-dimensional or start from the assumption of a steady liquid flow. We compare our simulations with experiments without making the above assumption to see if the flow reaches a steady state and under which conditions. We consider different flow situations by varying the diameter and the height of the column, the bubble street diameter and the gas fraction in the bubble street. We study the conditions under which the recirculating liquid cells can be observed. The influence of the wall-force and of the lateral-lift force also used by some other authors are analyzed.